Values

Values are the fundamental units of execution in Whiley and have value semantics, rather than reference semantics (as in many object-oriented languages).

| null | true | false |
| 123 | -99 | 0xFF |
| "Hello" | "new\n_line" |
| (1, 2, 3) | (true, null) |
| [1, 2, 3] | [1, "xyz"] |
| (name: "dave") | [x: 1, y: 0] |

Types

The Whiley programming language is statically typed, meaning that every expression has a type determined at compile time. Furthermore, evaluating an expression is guaranteed to yield a value of its type.

| null | bool | int |
| int | null | bool | int |
| (int, int) | (int, null, bool) |
| (int[]) | [bool[]] | (int|null)[] |
| (bool f) | [int len, int[] is] |

Expressions

The majority of work performed by a Whiley program is through the execution of expressions. Every expression produces a value and may have additional side effects.

- Arithmetic
  - x + 1
  - 2 * y
  - z - 1
  - (x + y) / 2
- Comparisons
  - x < y
  - 0 >= z
  - x == y
  - x != y
- Boolean
  - !x
  - x && y
  - x || y
  - x ==> y
- Arrays
  - [1, x+y]
  - [x in xs]
  - [x | y | x==y | x<=y]
  - [ls] ls[0] = [true; n]
  - [i,x,y] i in xs
  - [x: 1+y] x: f
  - [x: f[g]
- Records
  - all { i in 0..|xs| | xs[i]> 0 }
  - no { i in 0..|xs| | xs[i]< 0 }
  - some { i in 0..|xs| | xs[i]==0 }
  - x is null
  - x is int

Statements

The execution of a Whiley program is controlled by statements, which cause effects on the environment. Statements in Whiley do not produce values. Compound statements may contain other statements.

Variables are declared and initialised through variable declarations. Variables must be declared before being used.

| int x | int x = 1 | int x, int y |

Conditional statements control the flow of execution based on the result of a boolean expression.

| if x < 0: |
| ... |
| else: |
| ... |
| else if x > 0: |
| ... |

Looping statements control the flow of execution by repeating some sequence of statements zero or more times.

| while x<0: |
| ... |
| while x<0 |

Switch statements control execution flow by matching the result of an expression.

| switch x: |
| case 1: |
| x = x + 1 |
| case 1,2: |
| x = 0 |
| default: |
| x = 0 |

Return statements terminate the execution of a function or method and may return the result of an expression.

| return |
| return x + 3 |
| return x, y |

Assertion and assumption statements enable the programmer to express knowledge at a given point.

| assert x > 0 |
| assume x > 0 ==> y < 3 |

Break statements terminate loops early; debug statements enable output from functions; skip statements are a no-op.

| break |
| debug "got_here" |
| skip |
Declarations

A declaration declares a named entity within a source file and may refer to named entities in this or other source files and (in some cases) may recursively refer to itself.

Constant declarations define constants with known values at compile-time (they cannot be recursively defined).

```
class Ten
constant TEN is 10
constant TWENTY is TEN * 2
```

Type declarations define named types composed from other types (they may be recursively defined).

```
type Point is { int x, int y }
type Link is { LinkedList next, int data }
type LinkedList is null | Link
```

Function declarations define functions which are pure and may not have side-effects. They are guaranteed to return the same result given the same arguments, and are permitted within specifications.

```
function find(int[] xs, int x) -> int:
  ...
```

Method declarations define methods which are impure and may have side-effects. They cannot be used within specifications.

```
method main(System.Console console):
  console.out.println("Hello World")
```

Specifications

A precondition is a condition over the parameters of a function that must hold when the function is called. A postcondition is a condition over the return values of a function which is required to be true after the function is called.

```
function decrement(int x) -> (int y)
  // Parameter x must be greater than zero
  requires x > 0
  // Return must be greater or equal to zero
  ensures y >= 0
  // Return must be less than input
  ensures y < x:
    return x - 1
```

A data-type invariant is a constraint on the values of a declared type which must be true for any instance of it.

```
type nat is (int n) where n >= 0
```

A loop invariant is a property which holds before and after each iteration of the loop, such that: (1) the loop invariant must hold on entry to the loop; (2) assuming the loop invariant holds at the start of the loop body (along with the condition), it must hold at the end; (3) the loop invariant (along with the negated condition) can be assumed to hold immediately after the loop.

```
int i = 0
while i < x where i >= 0:
  i = i + 1
...
```

Examples

The following function computes the maximum value of two integer parameters.

```
function max(int x, int y) -> (int z)
  // must return either x or y
  ensures x == z || y == z
  // return must be as large as x and y
  ensures x <= z && y <= z:
    // implementation
    if x > y:
      return x
    else:
      return y
```

The following function uses a break to exit a while loop when the first element matching parameter x is found.

```
// Find index of matching element, or return -1
function indexOf(int[] xs, int x) -> int:
  int i = 0
  // while i < |xs|
  while i < |xs|
    where i >= 0:
      if xs[i] == x:
        return i
      i = i + 1
  return -1
```

The following function computes the length of a linked list.

```
// A linked list is either the empty list or a link
type LinkedList is null | Link
// A single link in a linked list
type Link is { LinkedList next, int data }

// Return length of linked list (i.e. number of links it contains)
function length(LinkedList l) -> int:
  if l is null
    // l now has type null
    return 0
  else:
    // l now has type {LinkedList next, int data}
    return 1 + length(l.next)
```

The following function reverses the values in a list of integers.

```
// size of lists are the same
function reverse(int[] xs) -> (int[] ys):
  // size of lists are the same
  ensures |xs| == |ys|:
    int i = 0
    int[] zs = xs
    // while i < |xs| where i >= 0 && |xs| == |zs|:
    while i < |xs| where i >= 0 && |xs| == |zs|:
      j = |xs| - (i+1)
      xs[i] = zs[j]
      i = i + 1
    return xs
```